Identification and Quantification of Pollutants That Have the Potential to Affect Evolutionary Processes

Are there specific pollutants or categories of pollutants that influence evolutionary processes, and, if so, to what extent can these effects be quantified? These questions require no answer if the premise is wrong, but if correct, then more serious consideration is warranted.

One example of the effects of pollution on evolution is "industrial melanism," which is described in numerous biology textbooks (*1*). The peppered moth (Biston betularia) found in England, was a lightly hued lepidopteran that used camouflage to blend into lichen-covered trees and thereby avoid predation. During the last century pollution from coal soot particles killed the lichens and blackened the trees, and if the peppered moth had not undergone mutation and natural selection and evolved into a different species with darkened coloration (B. carbonaria), the moth would have been eliminated. Nature provides similar examples of melanism that are not due to pollution but that also confers adaptive advantages in response to changing environmental conditions. Less familiar and still unproven examples include the alteration and disappearance of frog species throughout the world (*2*), which may or may not be partially attributable to global pollution. Coincidentally, the Department of the Interior has recently created The National Biological Survey, a new scientific agency asked to prepare biological surveys using an ecosystem mapping approach, and collect the information needed to effectively monitor and manage endangered species (*3*).

Examples of more complete ecosystems in the continental United States that are being altered by pollution in minute, subtle, and inexorable ways can be found from coast to coast. The megalopolis of Boston–New York–Philadelphia–Baltimore–Washington is rapidly being formed and was predicted to be boundary-less by the 21st century (*4*). The resultant concretion of the soil eliminates terrestrial habitats, and the release of effluent into the coastal waters has modified the elemental content and concentration of salt marshes. Primitive aquatic species are more vulnerable to change and more capable than advanced terrestrial species for rapid genetic modifications, so after adapting to reduced oxygen tension, light penetration, etc., it is more likely that they could undergo evolutionary changes. Some of the known consequences of environmental changes on terrestrial speciation caused by loss of habitat include the creation of "urban wildlife" populations of birds and mammals with novel home ranges, altered food chains and predator–prey relationships, different reproductive patterns, and modified behavioral responses, all of which portend genetic modifications for survival (*5*).

Move south to the Outer Banks, where anti-erosion projects and offshore oil drilling are current debates. Consider the consequences of changing the coastline and eliminating productive marshland to satisfy economic development or influencing the direction of the Gulf Stream, which transports nutrients along the ocean border. Would yet unproven but probable differences in the aquatic food chain lead to adaptive changes, and in turn culminate in changes in speciation or the natural evolutionary process? Farther south, the Florida Everglades provides a dramatic example of changes in the entire biological kingdom; disappearing plant and aquatic life in this fragile ecosystem cannot fail to disrupt the normal evolutionary processes necessary for sustainment. Attempts to control ecological systems for the benefit of society may seem cost-effective now, but what is the future expense?

The difficulty is that global ecosystems and the potential effects of pollutants on those systems are even more ephemeral to quantify. Computer models improve each year and can now model the ocean currents whose fluctuations control the weather for the entire world (*6*). What consequences would diluting the salt content of the ocean have on weather modification? The ocean current's cycle depends on the density of water in the North Atlantic caused by the higher salt content added by the Indian Ocean, so that the current sinks and flows back to the south with conveyer-belt precision. Somehow connected with this verifiable information is the inconsistent data on the melting of icecaps, the ozone layer, and the uncertain weather trends toward warming and cooling. Consider also the enormous biomass disappearing from Amazon rainforests, needed to continually consume carbon dioxide and produce oxygen to maintain the earth's atmosphere (*7-9*). Add to these alterations in global ecosystems the natural and unnatural calamities the earth undergoes: frequent volcanic eruptions, the Chernobyl accident, and the Gulf War tragedy, where millions of radioactive and nonradioactive particles were released into the atmosphere to cause germ cell line mutations, block UV irradiation, change weather and temperature patterns, and reduce growing seasons, all of which combine to ultimately affect all life patterns on earth. Can these chaotic events that result in extreme levels of air pollution fail to influence evolution?

Many question the seemingly minor effects of man-made pollution versus the incomparable effects of natural occurrences. This debate does not diminish our responsibility to quantify the effects of pollutants on the evolutionary process. Evolution is irreversible, and if we cannot identify pollutants that affect evolution and quantify their effects, there is no opportunity to even consider whether the outcome might be negative or positive and whether to prevent the changes.

Finally, can we identify pollutants or categories of pollutants that are more likely than others to affect evolution? Evolution requires genetic change and environmental factors, driven by selection. A priori, individual substances that can modify the genome are included, such as certain chemicals, UV and X-ray energy sources from the sun, and perhaps man-made currents of electricity. In addition, it is likely that natural events such as hurricanes and earthquakes could also play an important role in the evolutionary process, simply by altering the distribution of species and allowing selection to proceed.

It is unlikely that in my lifetime we will readily attain the knowledge to test the hypothesis that pollution exerts a global influence on evolution. I have more confidence that with the will to do so, and with the gain of greater scientific knowledge aided by the development of powerful parallel computational ability, eventually we can begin to quantify the effects of pollution on the evolutionary process, and maintain the diversity of life required by healthy ecosystems.

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